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Research Article

Responses of the refractory and free-milling gold ores to chloride leaching as an eco-friendly alternative to the cyanidation method

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ABSTRACT

Gold cyanidation has been of interest as a dissolution method for over a centry due to its high efficiency and selectivity to gold, and good stability. However, it has basic drawbacks such as long process time, high reagent costs, lower yields in refractory ores, cyanide regeneration complexity, and high toxicity of cyanide compounds. The present study investigates the potential of chloride leaching as as a faster and more sustainable alternative to dissolving gold from the refractory (RO) and free-milling (FO) ores with a focus on the novel application of sodium hypochlorite as an oxidant. The selected RO sample consisted of pyrite and quartz as the main mineral phases, with the gold encapsulated in pyrite. For FO, hematite and goethite were the main gold-bearing minerals. According to the diagnostic leaching tests, 95 % and 68 % of Au from the FO and RO, respectively, were dissolved after 48 h cyanidation. Cupric chloride, ferric chloride, hydrogen peroxide, and sodium hypochlorite were examined as oxidants but only the latter increased the oxidation-reduction potential (ORP) of the RO and FO pulps to over 800 and 1000 mV, respectively. Optimal leaching conditions, i.e. 1 M HCl, 5 M Cl^-, and 2 % NaOCl at 80 °C, recovered 94 % (FO) and 58 % (RO) gold within 3 h. This demonstrates an eightfold increase in reaction rate compared to cyanidation, with similar efficiency. The results highlight the potential of hypochlorite-assisted chloride leaching as a viable, greener alternative for rapid gold extraction, particularly from free-milling ores, with promising application to certain refractory ores.

1. Introduction

Cyanidation is the main hydrometallurgical process for gold extraction in industry, and the main advantage of cyanide is its high selectivity to gold. Hydrometallurgical methods are in great demand because they are accurate, predictable, and easily controllable, especially in the case of gold. Cyanide has been of interest as a dissolution agent for over 100 years due to its high efficiency, as well as high selectivity to gold and good complex stability. More than 18 % of the produced cyanide is globally used for gold dissolution [17].

China, Russia, Australia, and Canada with 375, 325, 314, and 195 tons of gold production, respectively, took the top four places for the largest gold producers in 2022 [10]. Whereas China's gold production has decreased from 383 to 368 tons from 2019 to 2020, mainly due to the government's policies on restricting cyanide application [28]. Iran produced approximately 8.5 tons of gold in 2022.

However, despite being used in 90 % of gold production, gold cyanidation is controversial due to the toxic nature of cyanide. Cyanide solution, as a lixiviant, has been questioned by the precious metals industry due to several factors that are primarily its toxicity and its ineffectiveness in the leaching of gold from complex ores. Although aqueous solutions of cyanide degrade rapidly in sunlight, the less-toxic products, such as cyanates and thiocyanates, may persist for some years. These concerns have led to a number of efforts for the development of non-cyanide gold dissolution methods, with thiosulfate, halides, thiourea, and thiocyanate, all have been proposed as alternatives to cyanide, with different advantages and drawbacks [20].

In acidic conditions, thiourea dissolves gold ten times faster than cyanides by forming a cationic complex. However, it is thermodynamically unstable in acidic and neutral environments. Moreover, thiourea is carcinogenic and susceptible to base metals like copper, lead, zinc, arsenic, and antimony, which may be present in the gold ore [4]. Thiocyanate is another effective Au leaching agent that works in an acidic environment, with a dissolving rate comparable to thiourea. It can be regenerated or converted into hydrocyanic acid or cyanide [3]. Compared with cyanide, nitrile compounds leach gold more slowly, are

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